# Testing the realism of model structures to identify karst system processes using water quality and quantity signatures


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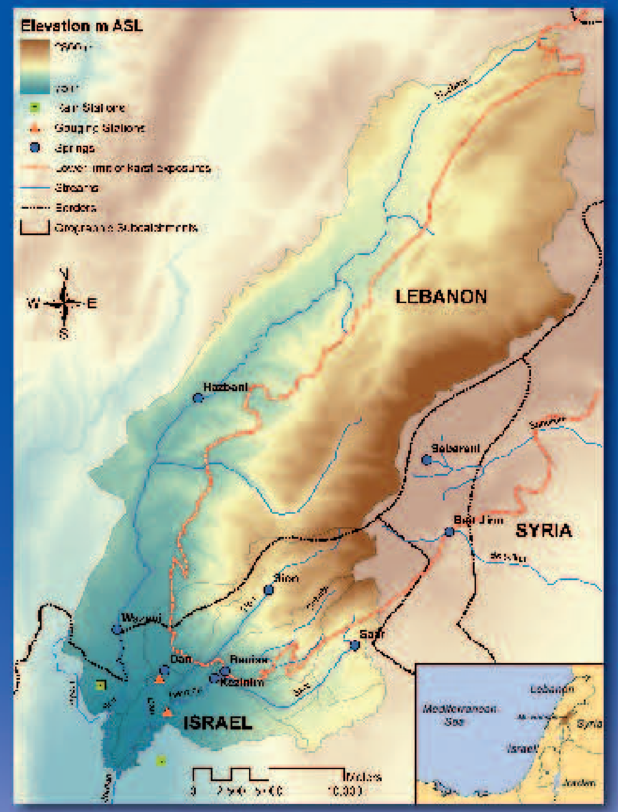
HYDROLOGY

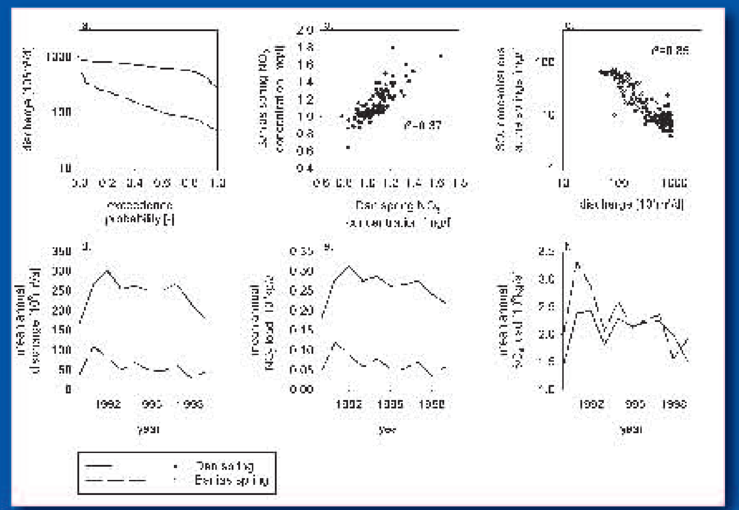
## THE FIELD



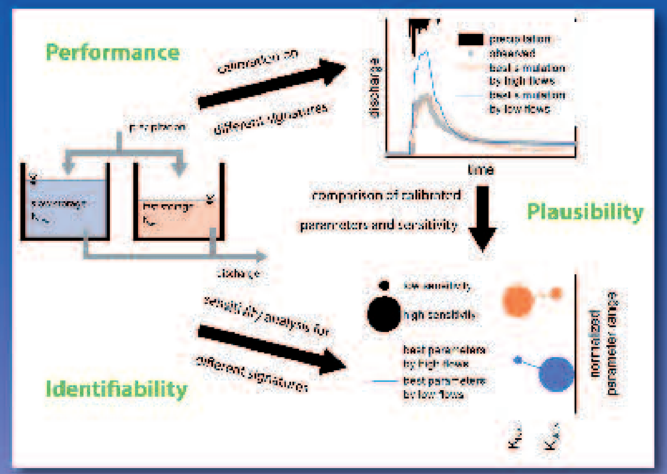

The study site is located at Mount Hermon in the Middle East. The catchment is mainly composed of Jurassic Limestone with a total surface catchment area of ~800 km² and altitudes up to 2814 m. The formation of cracks and fissures led to a deep karstification. There are two major karst springs draining the system: Dan spring and Banias spring. The larger one, Dan spring, is located at 200 m a.s.l. at an underground fault line, which allows water to pass overlying sandstones and marls. Banias spring is found 160 m higher, 4 km northeast of Dan spring, where limestone karst exposures meet sandstones and marls.

## THE RULES

We derived eight system signatures from water quantitiy and quality observations to describe the characteristic behavior of the two springs. They are based on different parts of the flow duration curves (high flows, median flows and low flows), the correlation of $NO_3$ between both springs, the correlation of discharge and $SO_4$ at each individual spring, and the annual water and solute balances.



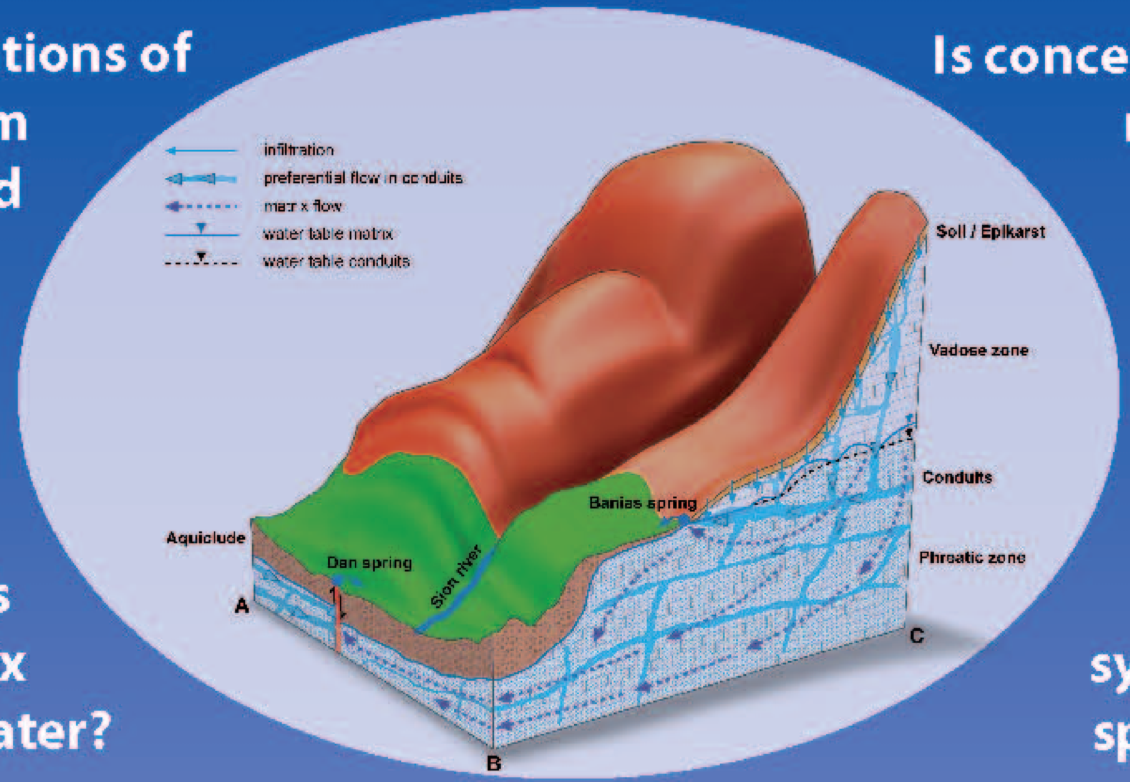
Four conceptual karst models were evaluated in three stages by (1) a test of performance, (2) the identifiability of their parameter, and (3) a test of plausibility. In stage 1 the models were calibrated to each single signature by comparing simulations and observations. In stage 2, the parameter identifiability for each model and each signature was found using Sobol's sensitivity analysis. In stage 3, simulation plausibility was derived by comparing the calibrated values of identifiable parameters for each individual signature. When a model failed in one of the three stages, it was discarded.




## KARST SYSTEM IDENTIFICATION!

Are contributions of water from conduits and matrix dominant?

Is concentrated or diffuse recharge taking place?



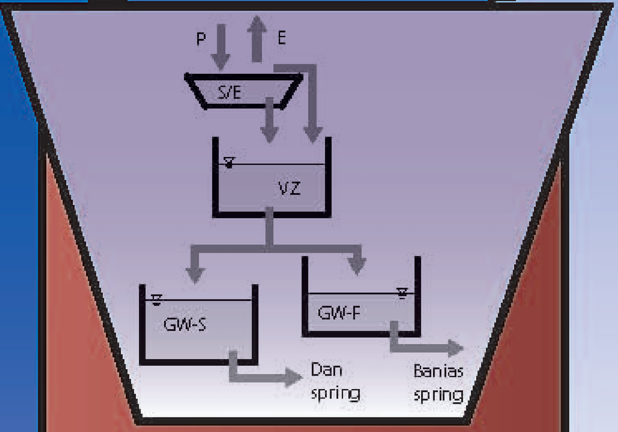

Do conduits and matrix exchange water?

Are the groundwater systems of the wto springs connected to each other?

### THE CANDIDATES

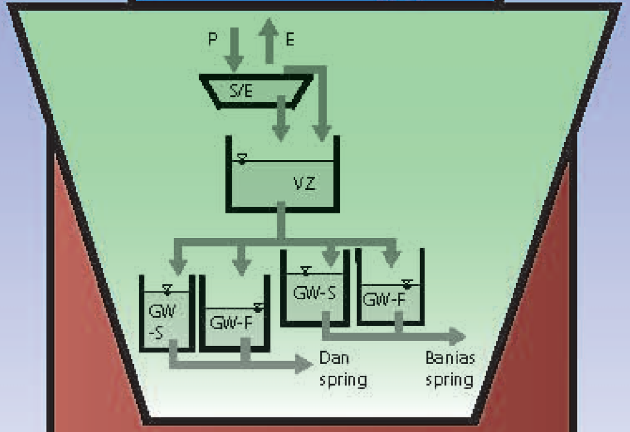
Four conceptual karst models with the same soil/epikarst and vadoze zone routines, but varying repsresentation of the groundwater system. Solute transport is simulated by assuming complete mixing in all the reservoirs. Except for model Orig, geogene dissolution of $SO_4$ in the matrix reservoirs is possible.

**Model Orig**



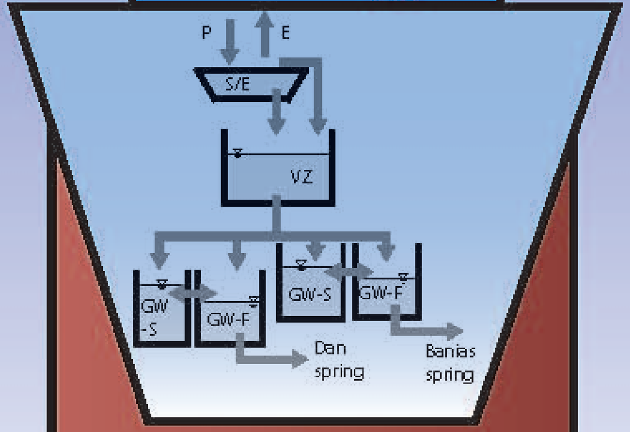

Slow groundwater system for Dan spring
Fast groundwater system for Banias spring
(7 parameters)

**Model $1_{VZ}$**



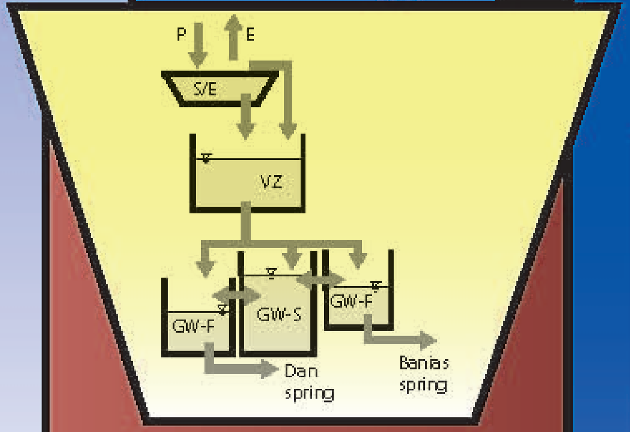

Separate matrix and conduit systems for both springs
No lateral exchange
(12 parameters)

**Model $2_{VZ}$**




Separate matrix and conduit systems
No exchange between the springs
(12 parameters)

**Model $3_{VZ}$**



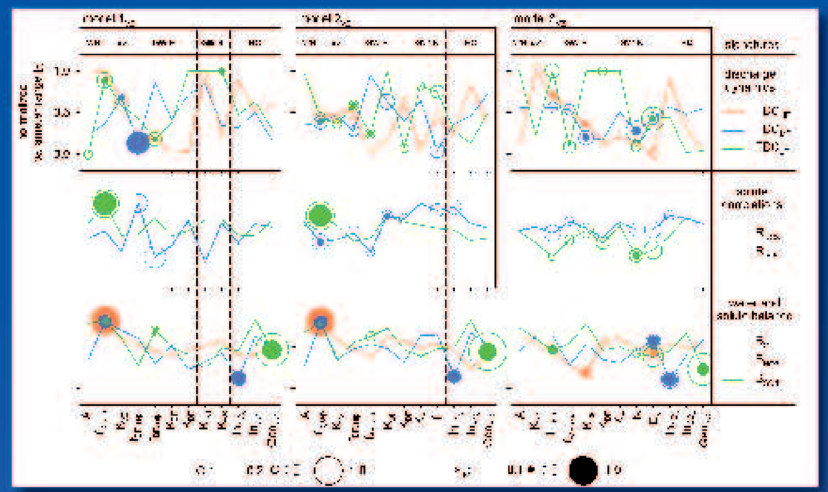

Separate conduit systems
Exchange between the springs via a common matrix system
(12 parameters)

## PLAY!

| signature | agreement / correlation for model | | | |
|---|---|---|---|---|
| | Orig | $1_{VZ}$ | $2_{VZ}$ | $3_{VZ}$ |
| $FDC_{HF}$ | 0.98 | 0.99 | 0.99 | 0.99 |
| $FDC_{MF}$ | 1 | 1 | 1 | 1 |
| $FDC_{LF}$ | 0.99 | 0.99 | 1 | 1 |
| $R_{NO3}$ | 1 | 1 | 1 | 1 |
| $R_{SO4}$ | 1 | 1 | 1 | 1 |
| $B_{Q}$ | 1 | 1 | 1 | 1 |
| $B_{NO3}$ | 1 | 1 | 1 | 1 |
| $B_{SO4}$ | 0.72 | 1 | 1 | 1 |

**STAGE 1**

In stage 1, all models reach high performance for the individual hydrodynamic system signatures. Only model Orig fails to reproduce the $SO_4$ solute balance and is therefore not reaching stage 2.



**STAGE 2**

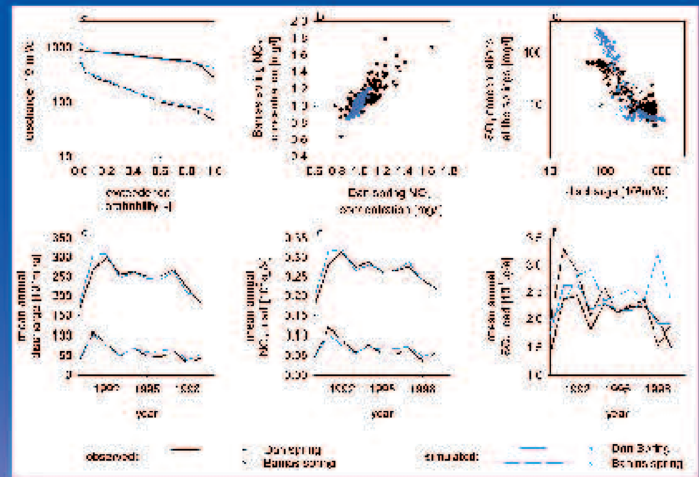
In stage 2, model $2_{VZ}$ and $3_{VZ}$ show identifiable paramaters for all different system signatures. Only A and $Geo_{SO4}$ remain not identifiable for both of them. For model $1_{VZ}$, a large part of the hydrodynamic parameters, especially the storage constants, remain unidentifiable for all system signatures and it is not passed to the final stage.

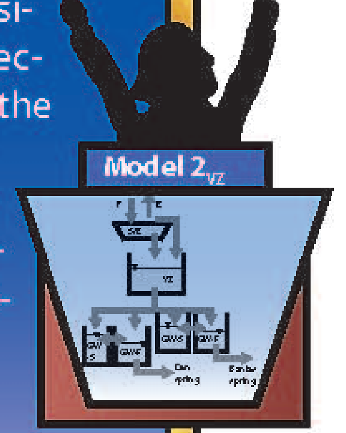
**STAGE 3**

In stage 3, there are only a few parameters that are identifiable for more than one signature. For model $2_{VZ}$ the parameter $f_{Q,sep}$ plots at the same position for $R_{SO4}$, $B_Q$ and $B_{NO3}$. Hence, three individual calibrations using three different signatures provide the same parameter value. For model $3_{VZ}$, four parameters are identifiable: $f_{F,sep}$, $K_{DF}$, $f_P$ and $D_V$. However, three of them plot at different positions for different signatures. This means that individual calibrations on different signatures result in different identifiable values for the same parameter. That indicates model structural deficiencies and model $3_{VZ}$ is discarded.

## FINAL SCORE

Model $2_{VZ}$ is able to reproduce adequately all system signatures. This indicates that its representation of karstic flow and storage processes approximates well the system functioning. Hence, our model evaluation strategy approach of deriving signatures from water quantity and quality data in combination with optimization and sensitivity analysis presents an objective way to clearly identify the functioning of complex hydrologic systems when there is not enough a priori information about their functioning.







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